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PATENT SPECIFICATION

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(54) METHOD AND APPARATUS FOR MONITORING ELECTROMAGNETIC RADIATION

(71) We, CLARKE CHAPMAN LIMITED (formerly known as Clarke Chapman-John Thompson Limited), a British Company, of Victoria Works, Gateshead, County Durham NE8 3HS, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to methods of monitoring electromagnetic radiation and apparatus for performing such methods particularly, though not exclusively a method and apparatus for flame monitoring.

Known flame monitoring systems use a monitor head responsive to Ultra Violet emission from a flame with an associated electro-magnetic amplifier or else use a photo-electric type of monitor head.

A small change in flame characteristic can cause a change in the position of the Ultra Violet emission thus giving rise to erratic response of the system and photo-electric devices are not able to discriminate between emission from a flame and background radiation.

An object of the invention is to provide a method and apparatus which avoids those drawbacks of known systems.

A method of monitoring electromagnetic radiation according to the invention comprises exposing a solid-state semiconductor device to the radiation, feeding the output from the device to an integrated circuit amplifier, feeding the output from the amplifier to a trigger circuit and deriving from the trigger circuit a warning or control signal, the trigger circuit including two transistors and two variable potentiometers by which negative and positive base currents of one of the two transistors can, respectively be set to allow a signal to be derived at different intensities of monitored radiation, the switch-off level of the apparatus being somewhat below the switch-on level.

Preferably, the solid-state device is a photo-transistor.

Preferably, the amplifier has a variable gain control and is preferably arranged to have positive gain.

Apparatus for performing the method according to the invention comprises a solid-state semi-conductor device connected to feed its output to an integrated circuit amplifier which is in turn connected to feed its output to a trigger circuit from which a warning or control system is derivable, the trigger circuit including two transistors and two variable potentiometers by which negative and positive base current of one of the two transistors can respectively be set to allow a signal to be derived at different intensities of monitored radiation, the switch-off level of the apparatus being somewhat below the switch-on level.

Preferably, the base of the first transistor receives the output from the amplifier, the first potentiometer being provided to vary the value of the fed-back current flowing from the base of the first transistor while it is non-conducting to the emitter of the first transistor and the second potentiometer being provided to vary the current applied to the base of the first transistor to hold it conducting.

One form of the method and apparatus for performing it will now be described with reference to the drawings accompanying the provisional specification.

Figure 1 is a schematic diagram of an electric circuit for performing the method;

Figures 4A to 4E are each graphs used during setting up of the circuit shown in Figure 1.

Figures 2 and 3 are schematic part-dia-

grams showing modifications which may be incorporated in the circuit of Figure 1.

The circuit shown in Figure 1 comprises a photo-transistor Tr1 which forms part of a monitor head (not shown) such as a head as described in our co-pending patent application No. 44100/72, Serial No. 1,425,455.

The monitor head is external to the remainder of the circuit which would be contained in a cabinet (not shown).

Transistors Tr5 and Tr6 are the power supply transistors, and operate in conjunction with R14 and D7 and R16 and D8 respectively, to stabilise the d.c. supply rails to ± 8 volts. The remainder of the power supply consists of diodes D3 — D6 and C2 and C3, the transformer T1 being used to reduce the mains voltage to a suitable level.

Incident electromagnetic radiation falling on the base area of the phototransistor Tr1 causes it to conduct, the point A becomes more positive and feeds a positive signal into an input amplifier A1. The amplifier A1 is an integrated-circuit amplifier and is connected to have a positive gain (i.e. input and output move in the same direction), the gain being determined by R3, R4 and the setting of VR1, the SET-GAIN potentiometer.

The output of the amplifier A1 feeds the point B, which can be regarded as a summing junction, for the several different feedbacks connected around the pair of transistors Tr2 and Tr3, which form a trigger circuit.

Initially Tr2 is non-conducting and so Tr3 conducts. There is no voltage across the potentiometer VR3. The only feedback is via R11, being a negative current flowing from the base of Tr2. The value of this base current can be set by another potentiometer Vr2, the SET-POINT potentiometer.

As Tr2 is an n-p-n transistor, this negative base current tends to hold the transistor Tr2 non conducting. The diode D1 is used to protect the base junction from excessive negative voltages.

As the output from the amplifier A1 goes more positive, corresponding to increased intensity of radiation on Tr1 current is driven through R6 and into the base of Tr2. The currents through R6 and R11 ultimately balance each other and no current then passes to the base of Tr2, which still remains non-conducting. If the amplifier output then goes very slightly positive the nett current at point B will be positive and will cause Tr2 to conduct.

This causes Tr3 to stop conducting and two results follow.

Firstly, Tr4 is caused to conduct via R15, so energising the relay RL1. Secondly, a voltage is applied across VR3, the SET HYSTERESIS potentiometer, which then passes a positive current through R10 to the base of Tr2, causing it to continue to conduct.

If the amplifier output voltage now reduces to slightly below the switch-on level, Tr2 continues to conduct. Adjustment of VR3 varies the hold-on current flowing into the base of Tr2.

For Tr2 to cease conducting the amplifier output voltage must fall low enough for some of the hysteresis current to be absorbed by the amplifier A1 and ultimately there will be insufficient base current to hold Tr2 conducting, and the relay RL1 will de-energise. The voltage across VR3 disappears as Tr3 ceases to conduct and the circuit returns to the original state.

R7 applies a fixed degree hysteresis to the system, and R5, R12 and R13 limit the effects of the three potentiometers. Lamps LP1 and LP2 give a visible indication of the position of the relay RL1.

Further relay contacts RL1-2 and RL1-3 are connected in circuits (not shown) controlling the supply of fuel to the burner monitored by Tr1 and giving further alarms as desired.

The values of the components shown in Figure 1 are tabulated below.

The phototransistor in a modification may be of the kind available from the Mullard Company under code BPX 70/72; or from the Texas Company under code T1X 51/2/3; or may be a photo-diode of the kind available from the Motorola Company under code MRD 3050 to 3056 or MRD 500 but the circuit may need modification in other respects to suit such other semi-conductor devices.

Other modifications are shown in Figures 2 and 3.

In Figure 2 additional diodes D9, D10 additional capacitor C4 and additional potentiometer VR4 are shown associated with the amplifier A1 so as to provide a variable time delay which enables the relay RL1 to be held energised under conditions of fluctuating intensity of incident radiation, such as where a flame being monitored is flickering.

The values of D9, D10, C4 and VR4 are not given as they would be chosen to suit the delay required. Values of other components might need to be altered to suit this modification.

Figure 3 shows another modification in which the relay RL1 is driven by an additional transistor Tr7, further components R17, C5 and D11 also being provided. This modification also allows a variable delay to be applied for example, a long delay of 25 to 30 seconds to enable the relay RL1 to be held energised under conditions of fluctuating intensity of monitored radiation. The values of the components are not given for

this modification as they would be chosen to suit the delay required.

The modifications shown in Figures 2 and 3 may be used separately or together.

. The method of using the circuit shown in Figure 1 will now be described in relation to monitoring of a flame of a burner in a boiler plant.

Before the circuit is set up, the monitor head (not shown) of which the phototransistor Tr1 forms part is positioned and the output voltage from it is read on a meter when the flame to be monitored is burning correctly. If necessary the monitor head can be moved to different positions to establish uniformity of reading.

At a selected position and orientation of the monitor head, the burner is shut down (i.e. no flame present) and the voltage reading is taken so as to derive a measure of the background radiation.

Experience allows one or other of the characteristics shown in Figures 4A to 4E to be selected as suitable for the particular flame concerned. Each characteristic corresponds to a particular value of setting on the SET POINT potentiometer VR2 and this is now adjusted accordingly.

The corresponding characteristic (suppose it is that shown in Figure 4D) is now used as follows: Gain-setting values are set out along the vertical base line and input voltage values are set out along the horizontal base line. At the voltage reading corresponding to flame full or (obtained earlier) (suppose it was 1.8 volts) there is a corresponding gain-setting given by the intersection of the vertical at 1.8 volts with the relay energisation curve RC. In Figure 4D this is a gain setting of value 3. The next higher value 4 is chosen and VR1 is adjusted accordingly.

This ensures that the signal from the monitor head at full flame is higher than the level required to energise the relay RL1.

Next, on the same characteristic sheet of Figure 4D the vertical through the input voltage corresponding to flame out (suppose it was 0.4 volts) is seen to intersect the horizontal through the value of gain setting previously found (4) at a point almost exactly on a broken line H-10 being one of a series H-10, H-8, H-6, H-4, H-2 and H-0.

These lines are hysteresis setting characteristics. The next characteristic to the right is chosen (H-8) and the potentiometer VR3 is adjusted accordingly to give this setting.

This ensures that the signal from any background radiation is less than that necessary to maintain the relay RL1 energised.

The circuit described above provides a greatly improved performance compared with known systems. It provides controls to adjust: —

(i) the value of radiation intensity at which the relay energises (VR2 with VR1)

(ii) the value of radiation intensity below which the relay de-energises (VR3 with VR1)

(iii) the gain of the amplifier (VR1);

With given settings for the controls as given by way of example above, the relay R1 remains energised provided the intensity of radiation falling on the base of Tr1 remains above the selected energisation point for the relay. The lamp LP2 is illuminated at this time. Variation in intensity such as arises when a monitored flame flickers, will not affect the relay so long as the variation does not cause a fall in intensity below the pre-selected value.

If the intensity of radiation falls below that pre-selected value, the relay de-energises and contact RL1-1 moves to the left and lamp LP1 is illuminated.

Contacts RL1-1 and RL1-3 also move to the right to change the state of other circuits; for example, in the case of flame monitoring to cause closure of a fuel valve supplying the flame being monitored and to sound an audible alarm.

As shown in Figure 1, the hysteresis is set by VR3 and by the fixed resistor R7.

The "set point" selected by VR2 dictates the value to which the incident intensity must rise (following de-energisation of the relay) before the relay energises again. The set hysteresis selected by VR3 dictates the width of the band over which the relay operates.

The modification described with reference to Figure 2 enables an integrating type of delay to be added to the circuit so that, where the intensity falls just below the point set for de-energisation of the relay but increases again within the time delay period to above the pre-selected value, the relay remains energised.

Such a facility is useful in certain conditions such as where a flame is subject to particular flickering modes.

The circuit modification described with reference to Figure 3 allows a further or alternative delay facility to be introduced to cope with intensity variations of relatively long period.

The circuit as shown in Figure 1 has a fixed time delay dictated by the values of the components C1 and associated resistors and this can be chosen to give a fixed time delay compatible with the radiation source being monitored, being a source not subject to fluctuations of intensity of such magnitude or frequency that demand the measures demonstrated in Figure 2 and 3.

The photo-transistor defined below in the list of component values is a lensed device and it has a relatively high sensitivity. As an alternative it is possible to use a device

which has a plain window instead of a lens (such for example as a photo-transistor of the kind available from the Mullard Company under code BPX29, a device similar to the lensed device quoted below in the component value list).

With such a modification the gain of the amplifier A1 could be increased many times to give the equivalent output by alteration of the values of the components associated with the amplifier A1. This variation would give rise to further scope for selection of the optimum response characteristics of the overall system.

A further modification (not shown) consists in replacing the electro mechanical relay RL1 with an array of thyristors associated with a transistor used to provide energisation of lamps and to provide any necessary control for operation of valve or other fuel control mechanism, as required for example in the case of flame monitoring in boiler plant.

Such a modification enables the whole of the circuit shown in Figure 1 to rely only on solid-state components which can be an important practical consideration for boiler plant applications.

The invention is not limited to monitoring of flames.

For example, the system may be applied to monitoring the radiation from a fixed source, the radiation traversing smoke emitted by a chimney.

Alternatively, the system may be applied to monitoring the operation of a valve, using a fixed source in a manner similar to that for smoke monitoring. Several valves in line could be monitored by a single radiation source and monitor head arranged at opposite ends of the line of valves.

Figures 4A, 4B, 4C & 4E are similar to Figure 4D referred to in detail above and the parameters are plotted along the coordinates in an exactly similar manner in all the Figure 4 graphs. The characteristics shown correspond to those in Figure 4D, the chain dotted characteristic having references with prefixes A, B, C or E before the respective references used in Figure 4D and the solid line characteristic also having the prefix A, B, C or E before its reference, which otherwise is the same as the reference used for the solid line characteristic in Figure 4D.

COMPONENT VALUES AND SPECIFICATION FOR FIGURE 1

RESISTORS (ALL ½ WATT 10%)		
R1	560 R	
R2	100 K	
R3	100 K	
R4	100 K	
R5	1 K	
R6	10 K	
R7	10 K	
R8	1 K	
R9	100 K	
R10	10 K	
R11	10 K	
R12	2.2 K	
R13	2.2 K	
R14	1 K	
R15	1 K	
R16	1 K	
VR1 — VR3	10K 1W Wire-Wound	Radiospares
TRANSISTORS		
TR1	BPX 25	Mullard
TR2	BC107	Newmarket
TR3	BC107	Newmarket
TR4	2N3704	Newmarket
TR5	2N3704	Newmarket
TR6	2N3702	Newmarket
DIODES		
D1 — D6	1N4001	Radiospares
D7, D8	BZY88, C8V2	Radiospares
CAPACITORS		
C1	4.7 uF 63V	Radiospares
C2, C3	1000 uF 15V	Radiospares

RELAY RL1		
MK 3P	Open type	Omron
AMPLIFIER A1		
741c		Radiospares
TRANSFORMER T1		
110V py	10V-0V-10V Sy	Radiospares

WHAT WE CLAIM IS:

1. A method of monitoring electromagnetic radiation comprising exposing a solid-state semi-conductor device to the radiation, feeding the output from the device to an integrated circuit amplifier, feeding the output from the amplifier to a trigger circuit and deriving from the trigger circuit a warning or control signal, the trigger circuit including two transistors and two variable potentiometers by which negative and positive base currents of one of the two transistors can, respectively, be set to allow a signal to be derived at different intensities of monitored radiation, the switch-off level of the apparatus being somewhat below the switch-on level.

2. A method according to claim 1, in which the radiation is derived from a flame produced by a burner in a boiler plant.

3. A method according to claim 1, in which the radiation is derived from a fixed source and traverses the emission from a chimney.

4. A method according to claim 1, in which the radiation is derived from a fixed source arranged at one side of a valve, the semi-conductor device being arranged at the opposite side of the valve.

5. A method according to claim 4, in which several valves in line are arranged between the source and the semi-conductor device.

6. A method according to any preceding claim, in which the semi-conductor device is a photo-transistor.

7. A method according to any preceding claim, in which the amplifier has variable gain control.

8. A method according to any preceding claim, in which the amplifier has positive gain.

9. Apparatus for performing the method according to any preceding claim, comprising a solid-state semi-conductor device connected to feed its output to an integrated circuit amplifier which is in turn connected to feed its output to a trigger circuit from which a warning or control signal is derivable, the trigger circuit including two transistors and two variable potentiometers by which negative and positive base currents of one of the two transistors can, respectively, be set to allow a signal to be derived at different intensities of monitored radiation, the switch-off level of the apparatus being somewhat below the switch-on level.

10. Apparatus according to claim 9, in which the base of the first transistor receives the output from the amplifier, a first of the two potentiometers being provided to vary the value of the fed-back current flowing from the base of the first transistor while it is non-conducting to the emitter of the first transistor, and the second potentiometer being provided to vary the current applied to the base of the first transistor to hold it conducting.

11. A method of monitoring electromagnetic radiation substantially as hereinbefore described with reference to Figure 1 of the drawings accompanying the provisional specification.

12. A method according to claim 11, but modified substantially as hereinbefore described with reference to Figure 2 of the drawings accompanying the provisional specification.

13. A method according to claim 11, or claim 12, but modified substantially as hereinbefore described with reference to Figure 3 of the drawings accompanying the provisional specification.

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Chartered Patent Agent,
Agent for the Applicants.

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1425456 PROVISIONAL SPECIFICATION
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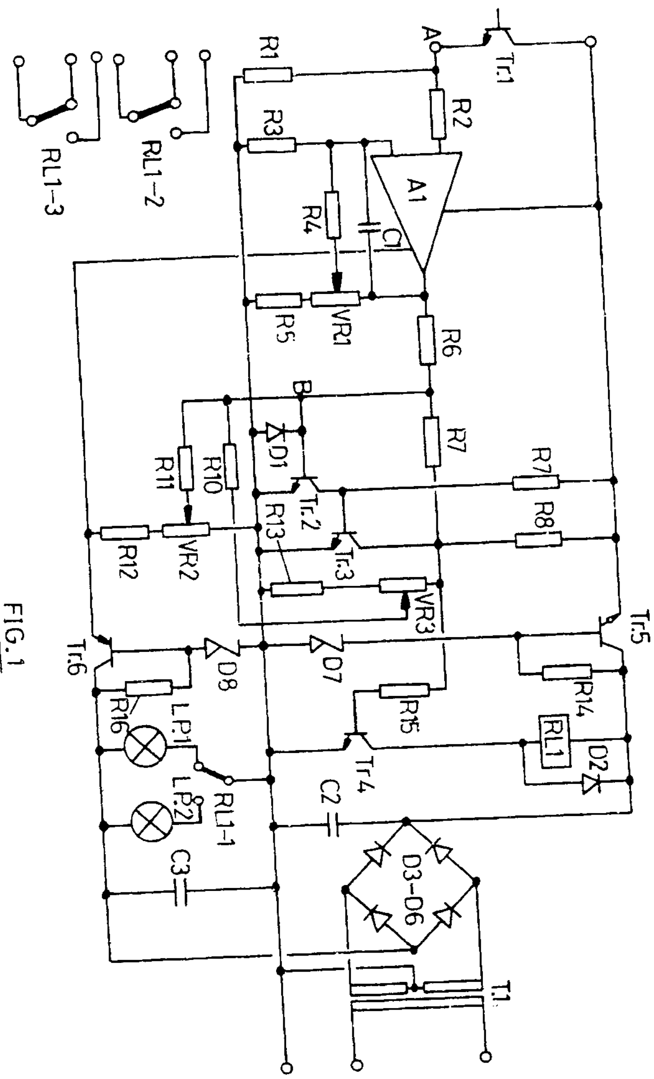
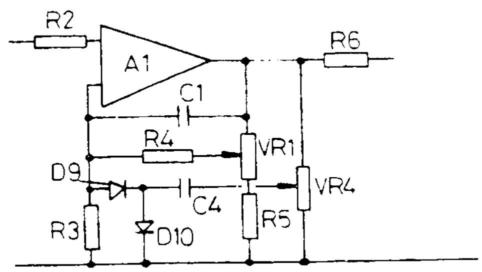


FIG.1



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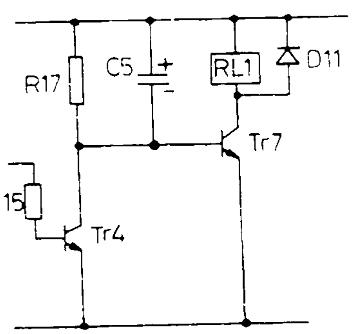

FIG. 3

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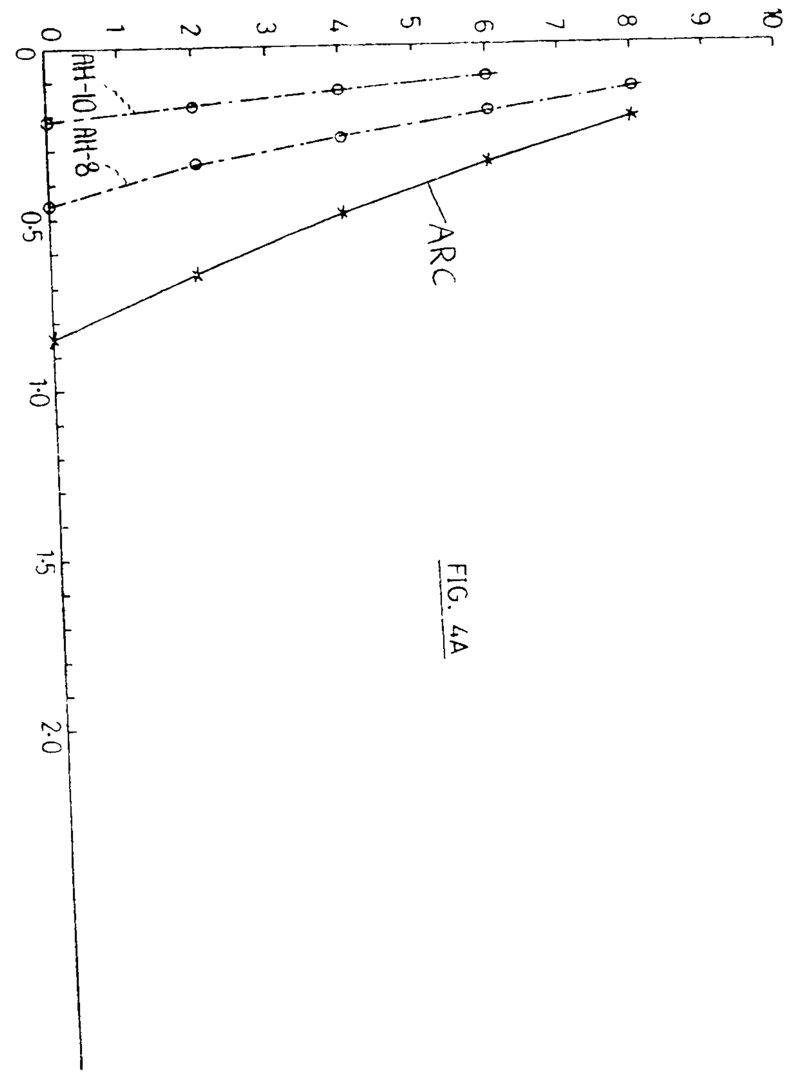

FIG. 4A

1425456 PROVISIONAL SPECIFICATION

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Sheet 4

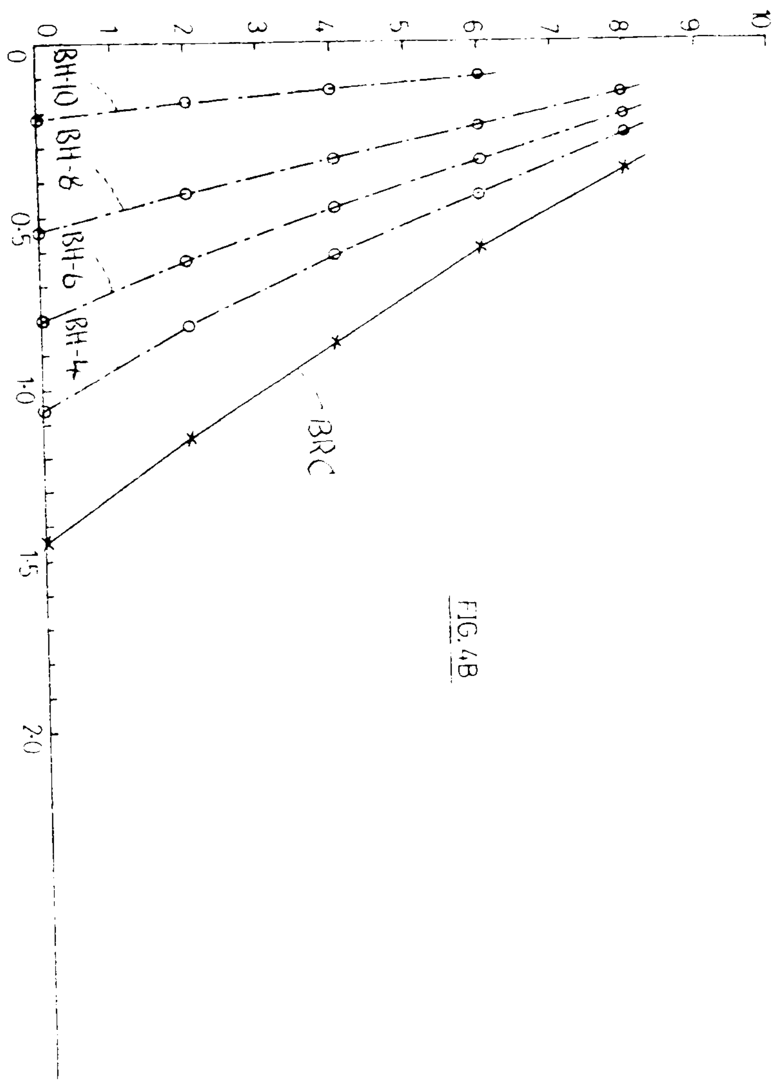

FIG. 4B

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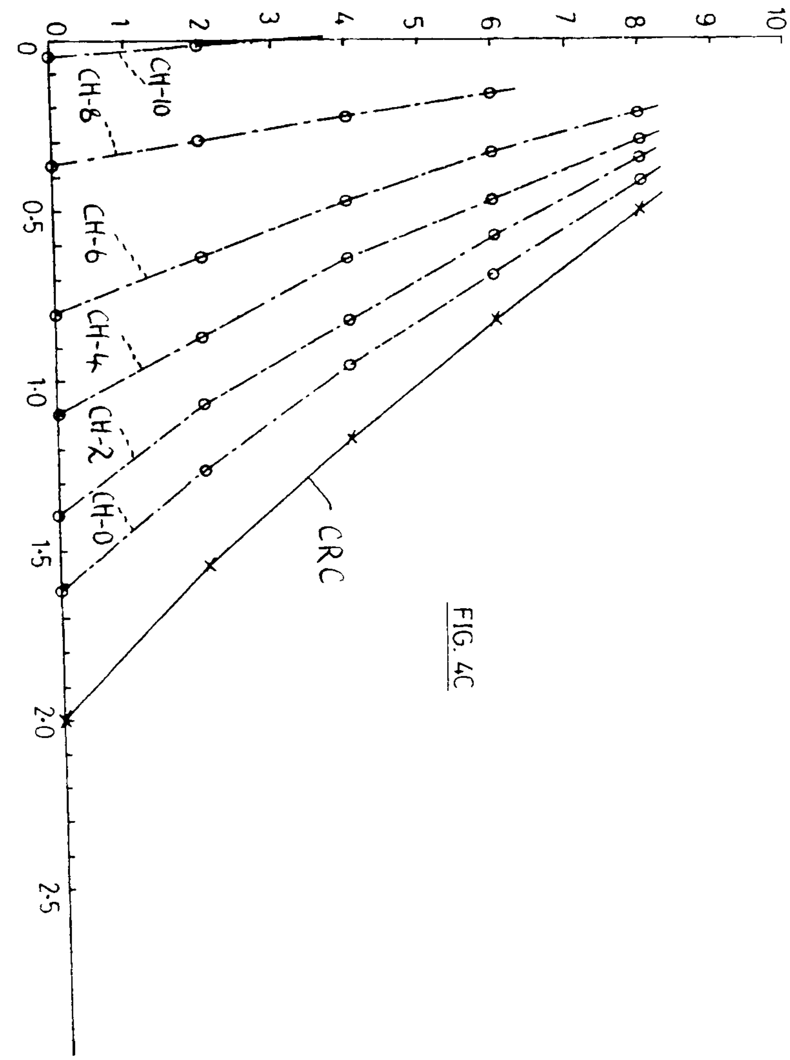

FIG. 4C

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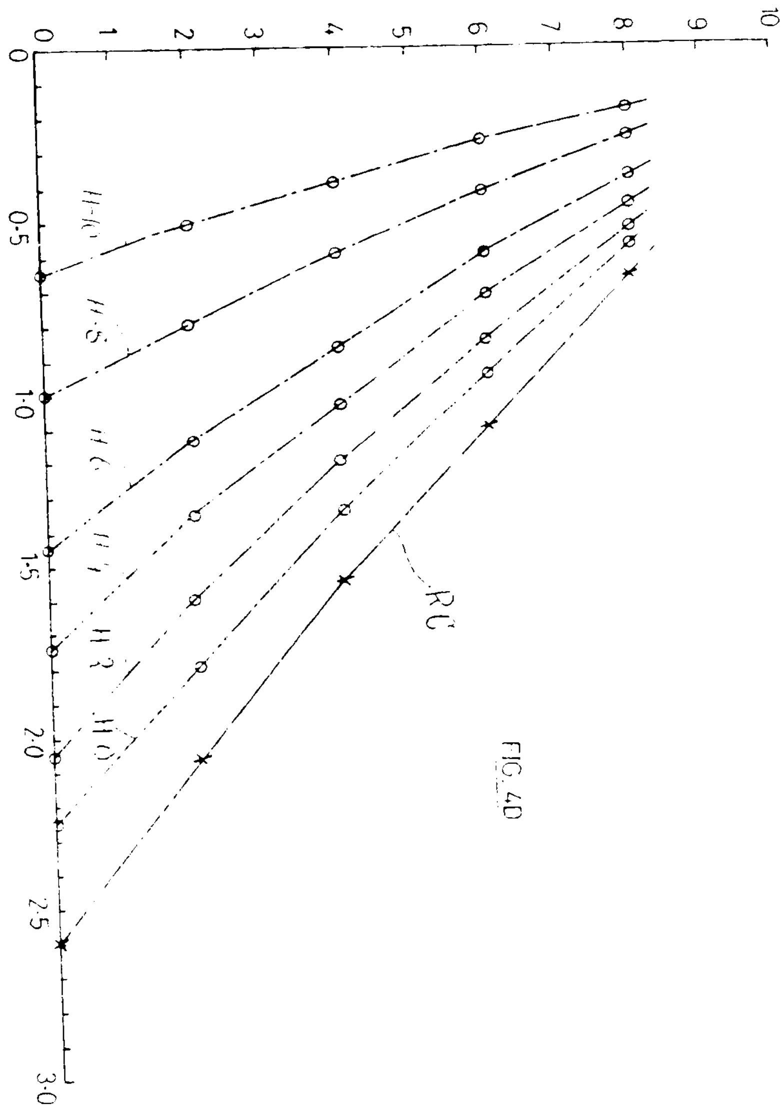

FIG. 4D

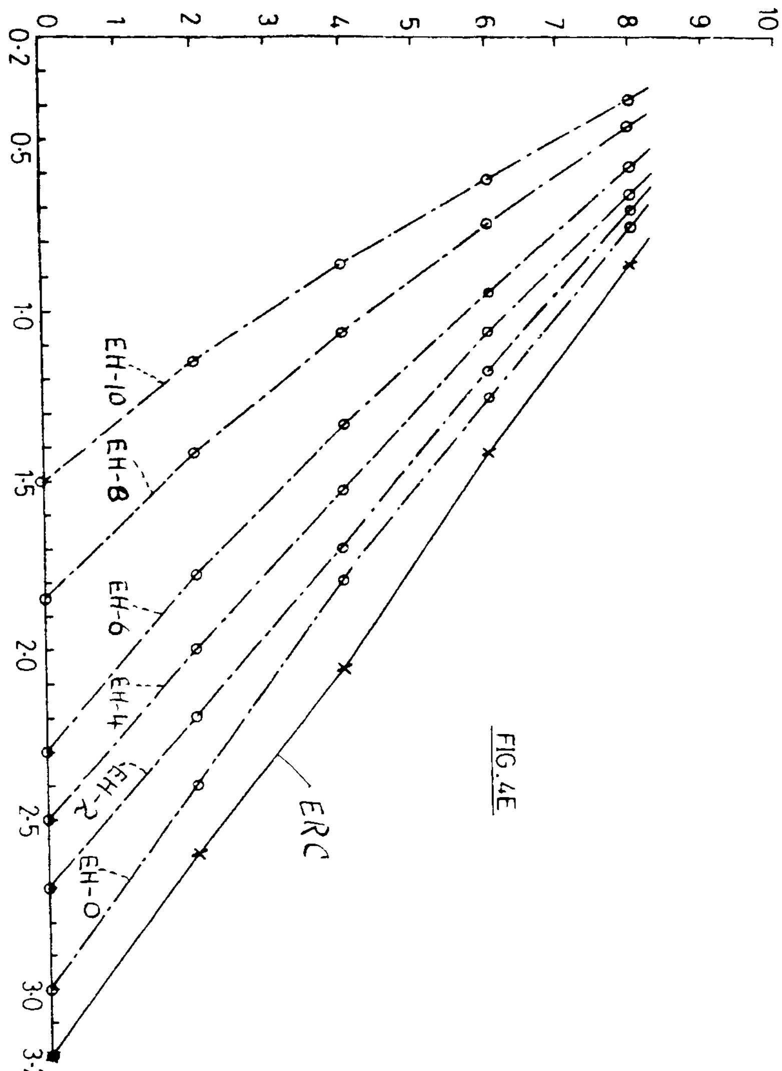
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FIG. 4E